PROGRAM REVIEW 1980-81

NORTHERN FOREST RESEARCH CENTRE

December 1981

NORTHERN FOREST RESEARCH CENTRE
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THE CANADIAN FORESTRY SERVICE
ENVIRONMENT CANADA

The Canadian Forestry Service (CFS) is the principal source of federal expertise in forestry. Its general objective is to promote the wise management and use of Canada's forest resources for the economic, social and environmental benefit of Canadians.

The following are the main functions of the CFS:

1. coordinating federal policies in order to promote better resource management and forest industry development,

2. providing scientific and technological leadership in forestry through research and development,

3. providing and analyzing national and international statistics and information as a basis for policy formulation,

4. developing and certifying codes and standards for wood product performance,

5. protecting Canada's forests from foreign pests,

6. fostering the potential use of the forest resource for energy, and

7. contributing to the environmental objectives of the Department of the Environment.

A number of federal agencies are involved in forestry programs, and a Federal Forestry Sector Strategy Committee has been established to coordinate federal forestry activities. The CFS has been designated the lead agency.

The Canadian Forestry Service is composed of a headquarters unit, six forest research centers and two national institutes. The forest research centers are responsive to regional priorities and maintain close liaison with the respective provincial government forestry departments. They also participate in, and frequently lead, national programs. The national institutes provide the focus for programs of national scope.

ENVIRONMENT CANADA

SERVICE CANADIEN DES FORETS
ENVIRONNEMENT CANADA

Le Service canadien des forêts (SCF) réunit la majorité des spécialistes fédéraux en foresterie. Son objectif général est de promouvoir l'aménagement et l'utilisation judicieux des ressources forestières du Canada pour le plus grand bien économique, social et environnemental des Canadiens.

Voici les principales fonctions du SCF:

1. coordonner les politiques fédérales afin de favoriser l'amélioration de la gestion des ressources et l'expansion de l'industrie forestière,

2. fournir une orientation scientifique et technologique dans le domaine de la foresterie, par la recherche et le développement,

3. fournir et analyser les statistiques et l'information nationales et internationales qui serviront à établir les politiques.

4. mettre au point et homologuer des codes et des normes en matière de rendement des produits du bois,

5. protéger les forêts canadiennes en luttant contre les ravageurs étrangers,

6. parrainer l'utilisation éventuelle des resources forestières pour la production d'énergie, et

7. adhérer aux objectifs environnementaux du ministère de l'Environnement.

Divers organismes fédéraux participent aux programmes forestiers, et un comité de la stratégie forestière fédérale a été créé pour coordonner les activités fédérales en matière de foresterie. Le SCF a été désigné organisme directeur.

Le Service canadien des forêts comprend une administration centrale, six centres de recherches forestières et deux instituts nationaux. Les centres de recherches forestières doivent répondre aux impératifs régionaux et entretenir une liaison étroite avec les ministères provinciaux des Forêts. Ils participent également à des programmes nationaux dont ils assument fréquemment la direction. Les instituts nationaux sont les foyers des programmes d'envergure nationale.

ENVIRONNEMENT CANADA

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DIRECTOR'S REPORT

The Northern Forest Research Centre (NoFRC) located in Edmonton, Alberta, is responsible for fulfilling the federal role in forestry research, development, and technology transfer in the three prairie provinces--Alberta, Saskatchewan, and Manitoba--and the Northwest Territories. This report on our programs reflects the progress made during the fiscal year 1980-81 in achieving work objectives.

The overall objective of the center is to conduct forest research and technology transfer activities in support of improved forest management for the economic, social, and environmental benefit of all Canadians. Coordination of federal policies to improve resource management and to encourage forest industry development is an integral part of the work program.

Progress toward the attainment of objectives and goals was facilitated by the implementation of a multiyear program plan covering all work areas. The current plan, covering the three-year period of 1979-80 to 1981-82, provides for the orderly identification, development, and integration of major research and technology transfer activities involving a staff of 117 and an operating budget of $4 million. Research activities continued to be organized under three programs: Environmental Forestry Research, Forest Resources Research, and Forestry Extension. The plan is based on the premise that there must be a more-systematic approach to research by 1) gathering and analyzing existing data for use in forest management planning and operations and 2) identifying those areas critical to systems planning and management and carrying out research in them. This approach recognizes the fact that provincial and federal forest resource management agencies and the forest industry have substantially increased their commitment to intensive forest management and are also assuming more responsibility for meeting their day-to-day or "spot fire" type of research needs.

Achievements in our research, development, and extension programs during the 1980-81 fiscal year are outlined in the main body of the text; organization, staff listing, expenditures, cost-shared agreements, contracts, and publications are detailed in the appendixes (A to F). Program accomplishments are briefly highlighted in the following paragraphs.

Environmental Forestry Research

A major study, on a cost-sharing basis with the Province of Alberta, was initiated to determine the impact of pollutant mixtures on forest vegetation and soils. Cooperative research with the Province of Manitoba continued to provide essential information pertaining to the detection and assessment of the effects of smelter effluents on vegetation and soils. The field phase of a land and vegetation resource inventory of Banff and Jasper national parks was completed. Forest hydrology research continued to provide additional information on the impact of vegetation manipulation to improve water yield and quality from the eastern slopes of the Rockies. NoFRC continued to contribute expertise in assessing the environmental impacts of industrial developments in Canada's north.

A major computer mapping system was ordered and will be used, in part, to demonstrate its application for development and manipulation of geographically referenced biomass inventory data. Direct Canadian Forestry Service involvement in the biogeoclimatic ecosystem classification of Alberta was terminated, but this center will continue to conduct research in site productivity.

More-effective transfer of information to resource managers is the ultimate justification of all program activities. Progress continued to be made in improving the quality of publications. A new publication series, the Forest Management Note, was initiated to inform resource managers of new developments of a practical nature.

Forest Resources Research

Field surveys were completed to provide comprehensive statistical descriptions of the major impacts of forestry and forest-based industries on the economies of the three prairie provinces. Ambitious studies were initiated to develop new silvicultural prescriptions and management tools, including predictive growth and yield models for key commercial tree species. A fire spread and containment model was developed, tested, and demonstrated to client agencies. A study of the fire detection system in Saskatchewan was completed, and fire researchers participated in fire boards of review for Riding Mountain and Wood Buffalo national parks. NoFRC continued to participate in the development and implementation of the Canadian Forest Resource Data Program and assumed responsibility for the publication of national statistics on reforestation. Several contract studies, totalling over $300,000, were conducted in support of ENFOR (ENergy from the FORest) program objectives. A PDP 11/60 minicomputer system became fully operational and now satisfies most computational and data base needs. Program staff organized or participated in major technology transfer activities including a workshop to demonstrate effects of cultural practices on growth and yield of lodgepole pine, a field meeting of the Regional Reforestation Technical Committee, and a symposium on the mountain pine beetle.

Forestry Extension

General and special surveys were conducted to monitor forest pests in the three prairie provinces and the Northwest Territories. The Forest Insect and Disease Survey (FIDS) also provided pest extension services to provincial agencies, the forest industry, municipalities, and the general public. Special emphasis was placed on the provision of advisory services in support of strategies for mountain pine beetle control. In the area of insect and disease management systems, studies were completed on the biological control of the larch sawfly and the analysis and synthesis of FIDS historical data. New studies were initiated to assess the effectiveness of herbicides in forest management and to evaluate tree mortality in young lodgepole pine plantations. Following a one-year absence, the

Two senior members of the management team retired during the program year. Dr. G.T. Silver, Regional Director, and Dr. R.W. Reid, Deputy Director and Program Manager, Environmental Forestry Research, left the Canadian Forestry Service after over 30 years of continuous and dedicated service. I am most appreciative of their efforts in maintaining the high caliber of our research programs and their contributions to improved forest management in the region.

A.D. Kiil
A/Regional Director of Forestry

ENVIRONMENTAL FORESTRY RESEARCH

PROJECT NOR-7

Reduction of damage from pollutants in the atmosphere

Objectives: To determine the impact of air pollutants from the extraction and processing of natural resources on forest vegetation and soils; to develop diagnostic techniques to assess the effects of pollutants both singly and in combinations on the forest systems; and to provide a capability to predict the long-term implications of pollutant deposition on plant and soil systems.

Achievements: The following industrial operations and their pollutants are the primary targets of the research:

Industrial operation	Major pollutants
Natural gas and oil extraction and processing	Sulfur dioxide, hydrocarbons, salt water, nitrogen oxides, hydrogen sulfide, and elemental sulfur
Metal mining and smelting	Sulfur dioxide, heavy metals (copper, zinc, nickel, cadmium, lead), and other particulates
Pulp and paper manufacturing	Sulfur gases, methyl mercaptan, dimethyl sulfide, sodium hydroxide, and ammonia

Base-line studies and descriptive observations have been completed on the pattern and impact of pollutant depositions in the Ft. McMurray and Cold Lake oil sands and the Flin Flon and Thompson mining and smelting areas. Soil and vegetation descriptions have been completed at these and other industrial sites, and the initial impact of air pollutants has been assessed. In the laboratory further research is being carried out on the effects of sulfur dioxide and heavy metals on tree establishment, physiology, and growth parameters and on species symptomology, sensitivity, and threshold levels of toxicity.

Impact assessments and preliminary results of both field and laboratory studies have been presented to the Manitoba Clean Environment Commission, International Nickel Co. of Canada, Imperial Oil, Syncrude, provincial departments of the environment, and other agencies as appropriate. A handbook on the visual diagnosis of air pollutant and natural stress symptoms on forest vegetation in western Canada was published, as were scientific articles on biochemical, physiological, and ecological aspects of air pollution impact on plants.

PROJECT NOR-13

Maintenance and improvement of water yield and quality

Objectives: To provide forest managers with practical management prescriptions and guidelines that will stabilize or improve the quantity, quality, and delivery time of water from forested areas.

Achievements: Three subbasins of the Marmot Experimental Watershed in the Kananaskis River valley, Alberta, have been calibrated. A commerical harvest of the Cabin subbasin did not increase sediment in the stream. Over 2000 one-tree-height in diameter circular openings were cleared on the Twin subbasin. These clearings contain about twice as much snow at peak accumulation as the uncleared areas between. Streamflow from the Twin subbasin is being evaluated against that of the Middle subbasin, which has not been harvested.

Numerous clearings less than 0.4 ha were created in aspen forest on the Streeter Experimental Watershed in the northern Porcupine Hills, Alberta. These were expected to retain snow on the upper slopes and to allow the meltwater to infiltrate the soil and appear as local spring flow. The preliminary result is a 48% increase in water yield during the first 3 years since treatment. Regrowth of vegetation and its effect on spring flow continue to be monitored.

Results from these watershed experiments are being used to verify a land-use hydrologic model (PROSPER plus a snowmelt routine). This model is to be one of the vehicles for transferring research findings into practical forest management prescriptions for water yield augmentation.

Results from other more-theoretical studies--mainly being carried out at the James River snow study site--are being used in the development of the land-use model. For instance, wind speed measured near the ground surface on 1- to 2-ha clearings in a 20-m tall lodgepole pine forest was one-tenth that measured above the canopy or in a 20-ha clearing. These data indicate that transpiration, which can be measured directly using our numerical simulation of the heat pulse velocity technique, can be reduced to a greater extent in these smaller clearings, and there is a subsequent greater potential for water yield increase than can occur from forests commercially clear-cut in larger blocks.

PROJECT NOR-22

Remote sensing application

Objectives: To develop and apply new remote sensing techniques and sampling designs for forest inventories and environmental management; to assess the usefulness of LANDSAT imagery for mapping vegetation types, landforms, logging, forest fires, and insect damage through a series of operational trials; to undertake research to improve LANDSAT interpretation techniques by means of image enhancement, pattern recognition, and development of interpretation keys.

Achievements: An operational trial of a multistaged fire and timber inventory in the Northwest Territories using LANDSAT imagery was established. An interactive resource information system on micro- and minicomputers is being developed. Large-scale aerial photography to assess regeneration on cutovers in eastern Manitoba was acquired in cooperation with Abitibi Price Inc. of Pine Falls. In cooperation with the Alberta Forest Service and the Forest Insect and Disease Survey, color aerial photographs were obtained on which mountain pine beetle infestations will be located and mapped.

A publication on a camera and interpretation system using low-level, large-scale, color photography for assessing forest regeneration was published, as were the proceedings of a workshop on the practical applications of remote sensing to timber inventory, which was held in Edmonton in late 1979. Lectures and laboratory instruction were provided for the photogrammetry portion of a new mandatory 2nd-year forestry engineering course at the University of Alberta.

PROJECT NOR-23

Ecological land classification of national parks

Objectives: To provide an ecological land classification of national parks in western Canada that includes land, soil, vegetation, wildlife, and aquatic resource components with an interpretation of the data collected for land-use planning and management.

Achievements: Soil surveys of Yoho (with the Alberta Institute of Pedology) and Waterton national parks have been completed and reports published; an ecological interpretation of the soils and vegetation of Yoho is in press. A land classification integrating soil and vegetation resources has been completed for the Lake Louise area of Banff National Park.

An ecological land classification of Banff and Jasper national parks has been completed; final reports for Banff and Jasper are in progress. Fieldwork for Kootenay, Glacier, and Mount Revelstoke national parks will commence in the summer of 1981.

Cooperating agencies are the Alberta Institute of Pedology (University of Alberta), Agriculture Canada, Canadian Wildlife Service, and Parks Canada.

PROJECT NOR-27

Biogeoclimatic ecosystem classification of the Province of Alberta

Objectives: To develop an ecological classification of the forested lands of Alberta for use by forest managers.

Achievements: This cooperative project with the Alberta Forest Service was initiated in 1976. Using Krajina's (University of British Columbia) ecological system of classification, 415 sample plots were established throughout the forested area of the province between 1976 and 1981. On each plot the soils and vegetation were examined, vegetation-environment relationships were assessed, and the plots were classified into plant associations. Plant associations represent the smallest homogeneous unit of forest ecosystems and are the functional unit for forest management operations such as site-specific stand improvement and silvicultural prescriptions for reforestation. A preliminary grouping of forest ecosystem types into the larger biogeoclimatic zones has been completed and a revised biogeoclimatic zone map for the forested area of Alberta prepared. Zones, which are mapped at a scale of 1:1 000 000, are used for broad regional planning such as land-use allocation and for devising broad protection, inventory, and reforestation strategies.

Fieldwork and a preliminary assessment of the data collected under this project are now completed, and our involvement is terminated. Subsequent data analysis and mapping will be completed by the Forest Research Branch of the Alberta Department of Energy and Natural Resources.

PROJECT NOR-28

Environmental impact assessments

Objectives: To assess the impact of proposed industrial developments (i.e., pipelines, roads, and oil and gas exploration north of 60° latitude) and to recommend measures to minimize or mitigate their impact; to develop environmental criteria for the design and rehabilitation of pipeline rights-of-way and auxilliary structures.

Achievements: In the recent past, impact assessments were carried out in connection with the Mackenzie Valley pipeline, Polar gas pipeline, Alaska gas pipeline, and Beaufort Sea hydrocarbon development. Future research will depend on short-term notices of requests for environmental impact assessments received from senior management of Environment Canada, Cabinet, and other federal agencies or departments.

Natural resource inventory surveys have been carried out in the Thompsen River, Banks Island, and Bathhurst Inlet areas, NWT, in connection with the proposed establishment of national parks.

Pending the need for or management requests to carry out additional environmental impact assessments, a research program to determine the ecological relationships that influence peat-land development will be initiated early in 1981.

PROJECT NOR-31

Climatic studies

Objectives: to determine the effect and degree of past short- and long-term climate variations on tree and forest growth; to determine quantitative and qualitative interrelationships between key climatic parameters and climate variations on forest biomass growth.

Achievements: This is a new project, and recent work has stressed the collection and analysis of available publications. In addition, 30 climate stations of a potential 120 in the prairie region and NWT are being analyzed to provide annual and seasonal temperature and precipitation trends and variations. North-south white spruce tree-ring sample transects were established along the 115° longitude W in Alberta and NWT in 1979 and 1980 and are proposed along the Saskatchewan-Manitoba boundary in 1981. Two ENFOR contracts (P-149 and P-150) are directly related to this project (Appendix E).

PROJECT NOR-32

Long-range transport of air pollutants (LRTAP)

Objectives: To determine the origin and extent to which the long-range transport of air pollutants are degrading terrestrial ecosystems, with specific reference to soils and vegetation.

Achievements: This project represents a portion of a federal government program on the impact of airborne pollutants on the natural environment and is being carried out under the auspices of an interdepartmental committee. The ultimate objective is to establish pollution control guidelines for the provinces and, by agreement, with the United States of America.

A network of permanent biomonitoring sites has been established in the vicinity of smelters in Flin Flon and Thompson, Manitoba. Studies have been undertaken to determine the effects of smelter effluents on rainfall quality, forest species, and soil processes. Similar studies will be carried out at the proposed heavy oil development at Cold Lake, Alberta.

Preliminary reports have been submitted to or presented at hearings of the Manitoba Clean Environment Commission.

PROJECT NOR-33

Technical and scientific information

Objectives: To provide information to all user clientele (scientific, technical, and public) that is relevant and timely at a reasonable cost using the complete range of communications techniques and available information at our disposal.

Achievements: NoFRC has evolved into the principal regional source of information relating to management and protection of commercial and recreational forests, watershed management, land classification, land use, air pollution, land spill diagnosis, and reclamation. About 8000 requests for information are received annually via the mail, and there are as many via telephone and personal contacts. Approximately 35 000 copies of Information Reports, 15 000 journal article reprints, 30 000 Pest Leaflets, 5000 Forest Management Notes, and 30 000 copies of regional Ecotours are distributed annually on a request basis. There are around 1400 organizations and individuals on our computerized mailing list. In 1980-81, 11 Information Reports, 33 journal articles, 4 Forest Management Notes, 8 miscellaneous publications, and the Regina-Winnipeg Ecotour were published.

FOREST RESOURCES RESEARCH

PROJECT NOR-3

Resource opportunities and policy guidelines

Objectives: To provide recommendations and economic guidelines to resource managers for improvement of the competitive position of the forest industry, management of the forest economy, regulation of trade and commerce, and improvement of employment opportunities.

Achievements: Forest industry surveys have been carried out in Alberta, Saskatchewan, and Manitoba to identify and describe primary wood-using industries and to estimate economic benefits, products flow, and the impact of the forest resource and its utilization on the provincial economies. Directories have been published listing information on products, current production, capacity, wood supply, markets, woodlands equipment, mill facilities, and employment for sawmills, planing mills, plywood and wood treating plants, and pulp, paper, fiberboard, and waferboard mills in Alberta and Manitoba. Reports outlining the economic impact of forest industries on the provincial economies are now in preparation. A survey of forest industries will be carried out in the Northwest Territories in the summer of 1981.

Cooperating agencies are the Alberta Department of Energy and Natural Resources, Alberta Forest Products Association, Central Forest Products Association (Manitoba & Saskatchewan), Manitoba Department of Natural Resources, and the Saskatchewan Department of Tourism and Renewable Resources.

PROJECT NOR-4

Yields of managed stands

Objectives: To provide forest management agencies with improved techniques, models, and guidelines for predicting growth and yield in commercially important cover types.

Achievements: A predictive growth model based on site and density has been developed for lodgepole pine in Alberta. Work continues on predictive models for jack pine and trembling aspen. Tree and stand growth simulator models are currently being developed. Yield tables for lodgepole pine and jack pine have been published.

Regeneration stocking standards, juvenile growth rates, and growth potential of advanced growth and residuals have been assessed and reports have been prepared.

Numerous long-term studies are in progress to provide prescriptions for spacing, thinning, and fertilization of lodgepole pine, jack pine, white spruce, and trembling aspen. Results are being reported as they become available.

PROJECT NOR-5

Fire management systems and guidelines

Objectives: To provide standards, operational guidelines, and decision aids to land managers that will reduce, at an acceptable cost, damage and loss from forest fires while considering the related economic, ecological, and social factors.

Achievements: Burning indexes for specific fuel types and other interpretive devices have been developed to refine and extend application of the Canadian Fire Weather Index. Studies are continuing on the effects of prescribed burning on plant communities in jack pine and black spruce forest types. Guidelines for prescribed burning in these cover types are now being prepared. The historical and ecological effects of wildfire and the use of prescribed fire as a management tool in maintaining and manipulating vegetation and enhancing wildlife habitat are being studied in several western national parks.

Research is continuing on evaluating the effectiveness of air tankers and retardants as measured by air-drop patterns, retardant properties, and static testing of air tankers. A slide-tape presentation on the "Effective use of air tankers, helitankers, and fire retardants" has been prepared and shown throughout much of the region. A fire detection appraisal study has been completed for Saskatchewan, the Northwest Territories, and Prince Albert and Wood Buffalo national parks. A program has been initiated in Saskatchewan to locate incipient lightning fires using an infrared Thermovision and a lightning location and protection system.

Preliminary decision-aid models, including a simple location-allocation model and an initial-attack simulation model, have been developed to assist fire management agencies in optimizing allocation and use of resources during demanding fire situations.

A considerable amount of time and effort throughout the year is devoted to technology transfer and providing provincial and other federal agencies with technical assistance and staff training as required.

PROJECT NOR-10

Silvicultural prescriptions

Objectives: To provide forest managers with information, guidelines, and prescriptions for improving the level of regional forest regeneration management in tree nurseries and in field planting operations.

Achievements: Past research concentrated on developing and assessing site preparation techniques (including scarification and prescribed burning) and container planting systems. More recently emphasis has been placed on preplanting

conditioning and overwintering techniques that will reduce losses and improve field performance of container stock. Field performance of both bare-root and container-grown stock planted under a range of field conditions is currently being assessed. As a prelminary step in the development of silvicultural prescriptions for the major tree species in the region, data banks are being established and computer modeling is being undertaken to integrate available knowledge for use by forest managers. In addition, research programs are being developed in the areas of tree physiology and site productivity for the major commerical tree species of the region.

The technology transfer function has become especially significant in terms of the rapid increase in high-technology greenhouse production of containerized seedlings at both government and industrial nurseries throughout the region. At the same time, there has been an expansion of bare-root stock production, requiring additional work in the area of nursery soil management and nutrition as well as insect and disease control.

In 1980 a joint Canadian Institute of Forestry-NoFRC workshop and field trip emphasizing the juvenile stand management of lodgepole pine was held. A federal-provincial nurseryman's meeting at which Dr. Nigel Burdett of the B.C. Ministry of Forests discussed the root regeneration potential of seedlings as it related to lifting, storage, and field performance of stock was well attended.

The Regional Reforestation Technical Committee was formed in 1978. Membership includes NoFRC and provincial or territorial forestry agencies in Manitoba, Saskatchewan, Alberta, and the NWT. The committee is set up to function as a means of information exchange on reforestation matters of both research and operational natures. The committee meets annually on a rotation basis between provinces, and the chairman (L.G. Brace of this center) reports to NoFRC's Regional Senior Advisory Committee.

PROJECT NOR-12

Tree improvement

Objectives: To improve the quality of reforestation stock for use by forest land managers by breeding or identifying and introducing genetically superior populations of commercial forest species.

Achievements: The selection and breeding program for jack pine, initiated in 1966, continued through 1980. Family test plantations have been established in three breeding districts extending from eastern Manitoba to western Saskatchewan. A clone bank that was established in 1977 near Wildwood, Alberta, and contains nearly 2000 grafted ramets was maintained. About 400 ramets of selected clones have been produced for three seed orchards to be established by provincial and industrial cooperators in Manitoba and Saskatchewan.

White spruce, black spruce, Norway spruce, red pine, Scots pine, and jack pine plantations established between 1958 and 1975 as part of national provenance

testing experiments have been maintained, and 15-year results have been published for Norway spruce, red pine, and Scots pine.

PROJECT NOR-29

Forest resource data

Objectives: To collect and interpret forestry statistics at the regional and national levels in order to provide advice and guidelines to resource managers and researchers in support of forest policy decision making.

Achievements: This is a newly initiated regional project that forms part of the Canadian Forest Resource Data Program. Statistics will be collected across the nation on subjects of interest to policy and decision makers at the political level; this includes current growing stock levels, depletions as a result of harvesting, fire, and insects and diseases, increased yields as a result of reforestation, and the implementation of stand treatments including thinning and fertilization. The collection of statistical data on silviculture across Canada is primarily the responsibility of this center. In addition to maintenance of a computerized system for the compilation and analysis of regional forestry statistics, periodic reports will be prepared and distributed and regional simulation models will be developed and tested for the purpose of providing statistical forecast trends.

PROJECT NOR-30

Forest resource management options

Objectives: To provide forest resource managers with planning and operational information to maximize the net benefits from integrated resource management activities.

Achievements: This is a recently initiated research program. A vast quantity of relevant data in the fields of forest economics, forest protection, reforestation, growth and yield, forest influences, and other forestry information that relates to integrated resource management is currently available. Some of this information has been or is being utilized, but the available data base and application procedures tend to be fragmented and incomplete. Initial emphasis will therefore be placed on the identification of data to satisfy the needs of the objective. The development of data bases and models will obviously depend on input from other research studies, both within and outside of the CFS, and on information previously published or available from forest management and related agencies in the region, but this research study will provide the mechanism and expertise for integrating and systematizing information within a framework of economic, social, and environmental factors.

Also included under this project is the synthesis of available data for predicting biomass of regionally important tree species and the integration of

existing and new information on biomass through the development of suitable data bases (Datatrieve) and models to facilitate conversion of conventional forest inventories to biomass inventories.

PROJECT NOR-34

Forest biomass as an energy source (ENFOR)

Objectives: To develop methodology to quantify the amount of forest biomass available for energy conversion in the region, assess its cost in use, and determine the physical and socioeconomic impact of its availability and use.

Achievements: ENFOR is the acronym for the "ENergy from the FORest" program funded by the federal Department of Energy, Mines, and Resources and administered by the Canadian Forestry Service. A number of contracts have been awarded to private organizations to develop methods for quantifying the amount of forest biomass in the region. Contracts initiated in 1980-81 are briefly described as follows:

1. Development of biomass prediction equations for 10 commercial tree species (P-92) (two contractors)

2. Development of a stand growth model for trembling aspen (P-102)

3. Development and demonstration of a regional biomass inventory system (P-148)

4. Impact of climate on boreal forest biomass through tree-ring analysis (P-149)

5. Literature review of the growth, yield, and biomass of tree species and other vegetation in the boreal forest (P-150)

6. Cost of harvesting and chipping of aspen for energy production (P-163)

Contractor, complete project title, expenditures, and scientific authority are listed in Appendix E. Publications outlining the results of this work are currently being prepared. In addition, a 1979-80 contract with Western Ecological Services (B.C.) Ltd. for "Upper limits of standing crop density and growth rates for woody species: a literature review" was completed.

PROJECT NOR-53

Computer services

Objectives: To provide an efficient and comprehensive facility for computation and information processing in order to satisfy the requirements of NoFRC's research and development programs.

Achievements: A PDP 11/60 computer has been installed and is being used for applications programming and both in-house and remote computing facilities. Data banks are being established for a number of research programs (silvicultural prescriptions, fire, mensuration, and economics), and a number of programs developed outside of the laboratory are being tested and modified to suit local conditions. The computing service is being utilized by more than 30 research and support staff each year, and the number of users is growing. The in-house computing system, using multiple interactive terminals and batch processing, has logged an average workload of 10 000 tasks per month.

A Keypad Editor and Minitab (an interactive statistics package) have been installed and will provide additional flexibility.

FORESTRY EXTENSION

PROJECT NOR-1

Detection and appraisal of tree pests and vegetative disturbances

Objectives: To gain an improved knowledge of major forest insects and diseases for the purpose of understanding and minimizing damage attributable to these organisms and to contribute to a national overview of important pests and their implications.

Achievements: Annual surveys of important pests and conspicuous forest damage have been conducted since 1941. Infestations of major insect and disease outbreaks have been monitored and their impact on the forest resource have been assessed. Major insect problems monitored in 1980-81 include the mountain pine beetle, spruce budworm, jack pine budworm, and forest tent caterpillar. Scleroderris cankers in plantations, pine stem rusts in tree nurseries, and Dutch elm disease in urban settings are the principal diseases undergoing investigation. In 1981-82 a report on forest depletion resulting from major pests in the region for the past 5 years (1976-81) will be compiled and incorporated into the Canadian Forest Resource Data Program.

A pest extension service for a wide variety of clientele and training sessions on major pests in this region for forestry personnel have continued. More than 2000 inquiries were processed in 1981. The insect reference collection, the disease reference collection, and the fungus culture collection have been maintained and upgraded. Taxonomical and biological studies of sawflies and tree rusts are continuing. A study of bioactive metabolites of forest disease pathogens is in progress in cooperation with chemists at the University of Alberta. A comprehensive analysis was completed of Forest Insect and Disease Survey data collected during 1945-69 in Manitoba and Saskatchewan on infestations of 21 major species of defoliators and factors affecting population trends; a publication on the subject will be available in 1981.

PROJECT NOR-9

Insect and disease management systems

Objectives: To provide standards and operational guidelines to resource managers that will reduce, at an acceptable cost, damage and loss from insects and diseases.

Achievements: A program initiated in 1972 to assess the efficacy of pesticides to control insects on shade, shelterbelt, and ornamental trees was completed. As a result of these trials, sufficient data have been submitted for registration review of 22 chemical products for the control of 33 insect pests attacking 22 species of trees and shrubs. Annual reports have been published and distributed. Current plans call for a study of the use of herbicides as a tool in forest management, particularly as related to plantation establishment.

Studies on the effects of natural biotic control, particularly the nuclear polyhedrosis virus, on the forest tent caterpillar and the effects of Olesicampe benefactor Hinz on larch sawfly larvae have been concluded.

Research to determine the species and abundance of cone and seed insects and their importance on the production of coniferous seed, primarily white spruce, will be initiated in 1981. A comprehensive survey will be undertaken of recently reforested lodgepole pine sites located at Hinton, Alberta, and jack pine plantations located in the Sandilands Forest Reserve in Manitoba in order to assess losses from insects, diseases, animals, climate, and other factors in juvenile stands.

PROJECT NOR-17

Forestry services

Objectives: To provide advisory services to forest resource managers in silviculture, forest management practices, and forest insect problems.

Achievements: The solutions to many forest management problems do not require long-term research. Often the answer lies in the application of existing knowledge. By working closely with provincial and industrial forest management personnel in defining a problem and selecting and testing promising forest management techniques, it is possible to upgrade forestry practices in the region. During the past year the following services were initiated or successfully completed:

1. Entomological advisory services were provided to provincial forestry clients and federal and provincial park managers. Mountain pine beetle infestations along the east slopes of the Rocky Mountains and Cypress Hills accounted for a high demand, particularly with regard to technical committees and public hearings on control activities.

2. A start was made on the development of silvicultural prescriptions for the reforestation of jack pine in the Sandilands Forest Reserve, Manitoba, based on past research performed by the CFS and operational trends identified by the Manitoba Department of Natural Resources.

3. A comprehensive report has been published on the field performance of container seedlings grown in the BC/CFS styroblock and the ARC sausage in Alberta and the Northwest Territories.

4. A publication on the effects of methods of logging and skidding aspen to reduce damage to understory spruce was published.

5. General liaison and advisory services were provided on the subjects of stand establishment, high yield silviculture, and nursery operations.

6. Assistance was provided in the economic survey of primary wood-using industries in Manitoba (Project NOR-3), in the assessment of harvesting and chipping methods for aspen to be used in the production of methane gas (ENFOR P-163), and in the remeasurement and compilation of data collected from a variety of research and development programs being carried out by the center's staff.

7. A variety of silvicultural demonstrations and trials were maintained in Manitoba and Saskatchewan, e.g., effects of harvesting techniques on white spruce, black spruce, and aspen regeneration, use of barrel and anchor chains to regenerate cut-over jack pine stands, and underplanting of aspen with white spruce.

PROJECT NOR-52

Research support services

Objectives: To provide support services to the research programs in the areas of electronics, library, photography, and soils laboratory analyses.

Achievements:

Electronics - constructed and repaired specialized scientific equipment for use in the laboratory and in the field, including a retardant fuel-burning table for the fire program.

Library - annually receives, indexes, and stores over 4000 publications and scientific and technical journals related to forestry; provides an interlibrary loan service and computer access to index publications listed by various agencies and abstracting services around the world.

Photography - prepares black-and-white and color photographs, charts, and slides for use in publications and audiovisual presentations; completed a series of 290 color slides on the effects of pollutants on forest vegetation for inclusion in a recently published Information Report.

Soils laboratory - over 14 000 individual laboratory analyses of soil and vegetation samples were carried out; a method for determining chloride in foliage samples was devised and a publication was prepared.

ADMINISTRATION

Objectives: To provide a system of financial control and accountability in accordance with statutory and regulatory requirements; to provide general administrative support services, including materiel management, records management, engineering, building maintenance, secretarial and office services, and vehicle fleet management.

Achievements: Financial management and accountability were conducted in accordance with the objectives of the center, and all accounts were closed at the fiscal year in a satisfactory manner. General secretarial services were improved with the acquisition of a word processor and a composer typesetter. The administration, with professional support, made an assessment of all equipment holdings and forecast a program to update specific equipment over the next 5-year period. Vehicle fleet management was further assessed and the number of units was reduced from 59 to 56. Physical plant maintenance schedules were adhered to, and the energy conservation program was fine-tuned to a further degree; savings are currently estimated at $180,000 per year compared with energy consumed at the 1973 level.

PUBLIC INFORMATION

Objectives: To provide the center with a public information service; to act as the channel through which contact is maintained with the general public and national, regional, and local news media; to produce booklets, news releases, exhibits, and audiovisuals; and to handle telephone and written inquiries from the general public.

Achievements: The Public Affairs Office, Western and Northern Region, Environment Canada, is responsible for NoFRC's public information program.

In October 1980 an open house held at NoFRC in conjunction with Environment Week drew 3500 people. Approximately 2500 container-grown blue spruce and 2000 public information brochures were handed out. Participants in the open house included the Canadian Forestry Service, Canadian Wildlife Service, Atmospheric Environment Service, Environmental Protection Service, and Parks Canada. Spin-offs from the open house included television coverage of NoFRC's fire retardant program and a five-part television series on Environment Canada, one segment of which was devoted to the Northern Forest Research Centre.

The ENFOR display prepared by CFS Ottawa was erected for the Energy Show held in Saskatoon, October 22-26. It is estimated that 100 000 people attended the show. This display and a locally produced display on Ecotours of the Trans-Canada Highway were used at the official opening of the Federal Building in Calgary in mid-November. Spin-offs included a comprehensive newspaper write-up in the Calgary Herald and radio coverage on CBC Calgary of the Ecotour program.

Media relations work conducted for distinguished visitors, significant meetings, and important research in progress (e.g., Dutch elm disease research) resulted in increased media coverage in the Edmonton Journal and on both the English and French electronic media in Edmonton.

An audiovisual on the research and development program of the center has been produced and is being shown to technical and scientific audiences as well as the general public.

APPENDIX A

NORTHERN FOREST RESEARCH CENTRE
ORGANIZATION CHART
(as of March 31, 1981)

PUBLIC INFORMATION
(Public Affairs Office, Environment Canada)

A/DIRECTOR
A.D. Kiil

ADMINISTRATION
A.M. Mont

ENVIRONMENTAL FORESTRY RESEARCH
Program Manager
Dr. S.S. Malhotra

- NOR-7 -- Air pollution (Dr. P.A. Addison)*
- NOR-13 -- Forest hydrology (R.H. Swanson)
- NOR-22 -- Remote sensing (C.L. Kirby)
- NOR-23 -- Land classification of national parks (W.D. Holland)
- NOR-27 -- Biogeoclimatic classification of Alberta (J.D. Johnson)
- NOR-28 -- Environmental impact (S.C. Zoltai)
- NOR-31 -- Climatic studies (Dr. J.M. Powell)
- NOR-32 -- Transport of air pollutants (LRTAP) (Dr. G.D. Hogan)
- NOR-33 -- Technical and scientific information (R.M. Waldron)

* Project leader in parentheses

FOREST RESOURCES RESEARCH
A/Program Manager
Dr. J.M. Powell

- NOR-3 -- Resource opportunities and policy guidelines (W.J. Ondro)
- NOR-4 -- Yields of managed stands (Dr. I.E. Bella)
- NOR-5 -- Fire management systems (D.E. Dubé)
- NOR 10 -- Silvicultural prescriptions (L.G. Brace)
- NOR-12 -- Tree improvement (Dr. J.I. Klein)
- NOR-29 -- Forest resource data (P.J. Golec)
- NOR-30 -- Resource management options
- NOR-34 -- Forest biomass (ENFOR) (C.L. Kirby)
- NOR-53 -- Computer services

FORESTRY EXTENSION
Head
H.J. Johnson

- NOR-1 -- Detection and appraisal of tree pests (Dr. Y. Hiratsuka)
- NOR-9 -- Insect and disease management systems (W.G.H. Ives)
- NOR-17 -- Forestry services (H.J. Johnson)
- NOR-52 -- Research support services
  - Electronics
  - Library
  - Photography
  - Soils laboratory

Staffing	Person-years
Scientific & professional	47
Technical	42
Administration	19
Operating	9
Total	117

APPENDIX B

NORTHERN FOREST RESEARCH CENTRE
STAFF LISTING
(as of March 31, 1981)

Regional Director of Forestry:	A.D. Kiil (Acting) Secretary - K. Conaty
Program Managers Environmental Forestry Research:	Dr. S.S. Malhotra Secretary - F. Jetha
Forest Resources Research:	Dr. J.M. Powell (acting) Secretary - K. Conaty
Head, Forestry Extension:	H.J. Johnson Secretary - F. Jetha
Regional Chief of Finance and Administration:	A.M. Mont
Public Information:	Public Affairs Office, Western and Northern Region, Environment Canada

RESEARCH AND DEVELOPMENT PROJECTS

ENVIRONMENTAL FORESTRY RESEARCH
(DR. S.S. MALHOTRA)

Project No.	Title	Professional Staff	Technical Staff
NOR-7	Reduction of damage from pollutants in the atmosphere	Dr. P.A. Addison (Project leader) J. Baker Soil chemist (vacant)	R.G. Radford J.I. Ridgway
NOR-13	Maintenance and improvement of water yield and quality	R.H. Swanson (Project leader) G.R. Hillman H. Steppuhn	P.A. Hurdle E.B. Robson Z. Fisera
NOR-22	Remote sensing application	C.L. Kirby (Project leader) R.J. Hall	
NOR-23	Ecological land classification of national parks	W.D. Holland (Project leader) Forest ecologist (vacant)	D.T. Allan J.R. Dyck

Project No.	Title	Professional Staff	Technical Staff
NOR-27	Biogeoclimatic ecosystem classification of the Province of Alberta	J.D. Johnson	
NOR-28	Environmental impact assessments	S.C. Zoltai (Project leader)	M.W. Ali
NOR-31	Climatic studies	Dr. J.M. Powell (Project leader)	N.B. Schultz
NOR-32	Long-range transport of air pollutants (LRTAP)	Dr. G.D. Hogan (Project leader) Radiation chemist (vacant)	O.K. Fenn
NOR-33	Technical and scientific information	R.M. Waldron (Project leader) J.K. Samoil	
	FOREST RESOURCES RESEARCH (DR. J.M. POWELL)		
NOR-3	Resource opportunities and policy guidelines	W.J. Ondro (Project leader) T.B. Williamson	R.A. Bohning J.P. De Franceschi G.R. Stevenson H.M. Stewart
NOR-4	Yields of managed stands	Dr. I.E. Bella (Project leader) R.C. Yang Mensurationist (vacant)	S.J. Lux
NOR-5	Fire management systems and guidelines	D.E. Dubé (Project leader) M.E. Alexander Z. Chrosciewicz R.J. Newstead	R.J. Lieskovsky M. Maffey C. Ogilvie Vacant
NOR-10	Silvicultural prescriptions	L.G. Brace (Project leader) W.J. Ball I.G.W. Corns I.J. Dymock I.K. Edwards H. Zalasky	F.M. Dendwick R.F. Huber J.J. van Dyck N.R. Walker
NOR-12	Tree improvement	Dr. J.I. Klein (Project leader)	A. Nanka

Project No.	Title	Professional Staff	Technical Staff
NOR-29	Forest resource data	P.J. Golec (Project leader)	
NOR-30	Forest resource management options	C. Lee T. Singh	
NOR-34	Forest biomass as an energy source (ENFOR)	C.L. Kirby (Project leader)	
NOR-53	Computer services		
	Computer Systems Analyst	W. Chow	
	Scientific Programmer Analyst	R.N. Leenders	
	Computer Operator		G. Johnston
	FORESTRY EXTENSION (H.J. JOHNSON)		
NOR-1	Detection and appraisal of tree pests and vegetative disturbances	Dr. Y. Hiratsuka (Project leader) B.H. Moody H.R. Wong	F.J. Emond M.G. Grandmaison P.J. Maruyama J. Petty G.N. Still D. Szlabey R.C. Tidsbury
NOR-9	Insect and disease management systems	W.G.H. Ives (Project leader) J.A. Muldrew	J.A. Drouin R.M. Smith
NOR-17	Forestry services	H.J. Johnson (Project leader) H.F. Cerezke K. Froning	H.S. Gates J.R. Gorman V.S. Kolabinski C.L. Rentz
NOR-52	Research support services		
	Electronics		P. Bihuniak
	Library	D.J.S. Robinson	E.M. Hopp
	Photography		P.S. Debnam
	Soils laboratory	Y.P. Kalra	J. Shuya

ADMINISTRATION
(A.M. MONT)

Position	Staff
Finance Officer	F. Allen
Senior Accounts Clerk	B.A. Ball
Vehicle and Accounts Clerk	Vacant
Purchasing Officer	J.E. Hodgins
Purchasing Clerk	T. Avenell
Senior Storesman	D.H. Oaks
Storesman	J.C. McLoughlin
Supervisor Officer Services	E.R. de Looper
Registry Clerk	A. Fulton
Receptionist-Clerk	T.B. Phillips
Word Processor and Composer Operators	E. Schiewe G. Wood
Stenographer	Vacant
Chief Engineer	K.W. Backhaus
Assistant Chief Engineer	H. Schoendube
Maintenance Engineers	F.H. Gardner P.K. Mosher
Electrician	J.P. de Deckere
Senior Maintenance Craftsman	S.T. Colistro
Maintenance Craftsman	B.A. Clinton
Groundskeeper	M. Sadoway

APPENDIX C

NORTHERN FOREST RESEARCH CENTRE EXPENDITURES 1980-81

Program area	Person years	Salaries $'000	Operations & maintenance[1] $'000	Capital $'000	Total $'000
Directorate (includes Program Managers)	5	178.3	76.6		254.9
Environmental forestry research	27	736.1	133.3	17.4	886.8
Forest resources research	36	880.8	139.4	17.1	1,037.3
Forestry extension	27	712.6	117.9	10.4	840.9
Administration	22	395.9	377.1	61.9	834.9
ENFOR[2]			286.8		286.8
LRTAP[3]			16.5	153.7	170.2
Cost-shared agreements[4]			121.6		121.6
Total	117	2,903.7	1,269.2	260.5	4,433.4

[1] Includes contracts, see Appendix E.

[2] ENergy from the FORest (Project NOR-34) funded by Canada Department of Energy, Mines, and Resources.

[3] Long-Range Transport of Air Pollutants (Project NOR-32) funded by Environment Canada.

[4] See Appendix D.

APPENDIX D

NORTHERN FOREST RESEARCH CENTRE COST-SHARED AGREEMENTS AND EXPENDITURES 1980-81

Funding agency	Program	Project	Operations & maintenance $'000	R & D contracts[1] $'000
Alberta Department of Energy & Renewable Resources	Control of rust on tree seedlings (Smoky Lake Nursery)	NOR-1		4.8
	Development of an initial-attack model for fire operations in the Peace River Forest	NOR-5		3.7
	Container-seedling planting trials	NOR-10	3.6	
	Biogeoclimatic classification of forest lands	NOR-27	6.2	
Alberta Department of Environment	Impact of air pollutants	NOR-7	28.6	
Environment Canada, Parks Service	Ecological land classification of Banff & Jasper national parks	NOR-23	32.4	
Manitoba Department of Natural Resources	Primary wood-using industries survey	NOR-3	6.5	
Manitoba Department of the Environment	Heavy metals pollution	NOR-7	20.8	
Saskatchewan Department of Tourism and Renewable Resources	Primary wood-using industries survey	NOR-3	15.0	
Total			113.1	8.5

[1] See Appendix E.

APPENDIX E

NORTHERN FOREST RESEARCH CENTRE CONTRACTS[1] LET OR SUPERVISED AND EXPENDITURES IN 1980-81

Contractor	Title	Amount $	Scientific authority
Alberta Ecosystem Consultants Ltd. P.O. Box 1414 Hinton, Alberta	Determination of the specific gravity of wood samples on various tree species in the prairie provinces (P-92)	11,000	T. Singh
	Provision of fuel classification and fuel analysis procedures	10,050	D. Dubé
	Study of initial fire-attack operations in the Peace River Forest through development of an initial-attack model	3,750	D. Dubé
Allen, E. 12607 - 49 Avenue Edmonton, Alberta	Collection and examination of nursery tree seedlings for rust	4,800	Y. Hiratsuka
Coban Institute, The Resource Management Consultants 8441 - 14 Avenue Edmonton, Alberta	Costs of harvesting and chipping aspen stands for energy production (P-163)	54,060	W.J. Ondro
Delisle, G. 10, 11008 - 100 Avenue Edmonton, Alberta	Graphical layout of computer air-drop test pattern profiles	1,395	R. Lieskovsky

APPENDIX E continued

Contractor	Title	Amount $	Scientific authority
Department of Forest Science University of Alberta 3 - 31 University Hall Edmonton, Alberta	Development of a stand growth model for trembling aspen in the prairie provinces of Canada (P-102)	38,160	I.E. Bella
Forintek Canada Corp. Western Laboratory 6620 N.W. Marine Drive Vancouver, B.C.	Impact of climatic variation on the boreal forest biomass through use of tree-ring analysis (P-149)	18,000	J.M. Powell
Systemhouse Ltd. 99 Bank Street Ottawa, Ontario	Development and demonstration of a forest biomass inventory (P-148)	96,455	C.L. Kirby
Western Ecological Services (B.C.) Ltd. Marine Technology Centre 9865 West Saanich Road R.R. 2 Sidney, B.C.	To perform an extensive literature survey of the growth, yield, and biomass of different tree species and other vegetation present in the boreal zone (P-150)	12,448	J.M. Powell
Woodlot Service (1978) Ltd. 320 Maple Street Fredericton, N.B.	The selection, felling, measurement, weighing, and subsampling of main commercial species within the prairies and NWT (P-92)	35,855	T. Singh

1 Contracts with 'P' numbers form part of the ENFOR program (Project NOR-34). Contract P-92 is being carried out by two contractors, Alberta Ecosystem Consultants Ltd. and Woodlot Service (1978) Ltd.

APPENDIX F

NORTHERN FOREST RESEARCH CENTRE PUBLICATIONS 1980-81

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Ayer, W.A., S.P. Lee, A. Tsuneda, and Y. Hiratsuka. 1980. The isolation, identification, and bioassay of the antifungal metabolites produced by Monocillium nordinii. Can. J. Microbiol. 26(7):766-773.

Ball, W.J. 1980. Plantation performance in perspective. Environ. Can., Can. For. Serv., North. For. Res. Cent. Edmonton, Alberta. For. Manage. Note 4.

Bella, I.E., and J.P. De Franceschi. 1980. Biomass productivity of young aspen stands in western Canada. Environ. Can., Can. For. Serv., North. For. Res. Cent. Edmonton, Alberta. Inf. Rep. NOR-X-219.

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Froning, K. 1980. Logging hardwoods to reduce damage to white spruce understory. Environ. Can., Can. For. Serv., North. For. Res. Cent. Edmonton, Alberta. Inf. Rep. NOR-X-229.

Hargesheimer, E.E., M.J. Apps, and S.S. Malhotra. 1980. Determination of vanadium in jack pine needles using neutron activation analysis. Environ. Technol. Lett. 1:273-282.

Hiratsuka, Y. 1980. Fungi. Pages 45-46 in A nature guide to Alberta. Provincial Museum of Alberta Publication 5.

Hiratsuka, Y., and N. Hiratsuka. 1980. Morphology of spermogonia and taxonomy of rust fungi. Rep. Tottori Mycol. Inst. 18:257-268.

Hiratsuka, Y., H.F. Cerezke, and J. Petty. 1980. Forest insect and disease conditions in Alberta, Saskatchewan, Manitoba, and the Northwest Territories in 1979 and predictions for 1980. Environ. Can., Can. For. Serv., North. For. Res. Cent. Edmonton, Alberta. Inf. Rep. NOR-X-225.

Holland, W.D., and I.G.W. Corns. 1980. Forest-soil relationships in western Alberta and reconstruction of forest soils in reclamation. Pages 60-73 in Ziemkiewicz, P.F., S.K. Takyi, and H. Reiger (eds.). Proceedings: Workshop on reconstruction of forest soils in reclamation, April 8-9, 1980, Edmonton. Alberta Land Conservation and Reclamation Council Report RRTAC 80-4.

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Kirby, C.L. 1980. A camera and interpretation system for assessment of forest regeneration. Environ. Can., Can. For. Serv., North. For. Res. Cent. Edmonton, Alberta. Inf. Rep. NOR-X-221.

Kirby, C.L. 1980. Applications of multistaged and multiphased timber inventories. Pages 124-126 in C.L. Kirby and R.J. Hall (compilers). Practical applications of remote sensing to timber inventory. Proceedings of a workshop held September 26-28, 1979, in Edmonton, Alberta. Environ. Can., Can. For. Serv., North. For. Res. Cent. Edmonton, Alberta. Inf. Rep. NOR-X-224.

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Ondro, W.J., and D.V. Love. 1979. Growth response of northern hardwoods to partial cutting in southern Ontario. For. Chron. 55(1):13-16.

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